

U.S. Patent Application Serial No. 09/642,883
Response Under 37 C.F.R. §1.116 dated December 22, 2003
Reply to the Final Rejection of March 20, 2003
Attorney's Docket No. 001035

Amendments to the Claims

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

Claim 1 (Canceled).

Claim 2 (Currently Amended): ~~The A~~ plane diffraction grating ~~according to claim 1 with grooves formed on a surface thereof, the plane diffraction grating being~~ rotated about a rotational axis which is normal to the surface, and being characterized in that a profile of the grooves at a radial area is determined depending on an azimuthal position ϕ of the area about a rotational center defined as a foot of the rotational axis on the surface of the plane diffraction grating for maximizing a diffraction efficiency of the radial area,

wherein the plane diffraction grating is a blazed type, and a blaze angle θ_0 of the grooves in an area along an original line at the azimuthal angle $\phi = 0$ which is perpendicular to the grooves is set as:

$$\theta_0 = \frac{\alpha + \beta}{2},$$

where α is an angle of an incident ray from a normal to the surface of the plane diffraction grating in the area, and β is an angle of a diffraction ray from the normal, and

a blaze angle $\theta\phi$ of the grooves in an area along a line at the azimuthal position is set as

$$\sin \theta_{\phi} = \sin \theta_0 \sqrt{\frac{1 + \tan^2 \phi}{1 + \tan^2 \phi \sin^2 \theta_0}}.$$

Claim 3 (Previously Presented): The plane diffraction grating according to claim 2, wherein:

the surface of the plane diffraction grating is covered with a multiple-layer coating to improve reflectivity;

a unit thickness $d_{b\phi}$ of the multiple-layer coating in the area along the original line at the azimuthal angle ϕ satisfies the equation:

$$m_b \lambda = 2d_{b\phi} R_{\alpha\phi} \cos(\alpha - \theta_0)$$

where

m_b is the diffraction order,

λ is the wavelength of the light diffracted by the area,

$$R_{\alpha\phi} = \sqrt{1 - (2\delta_{\phi} - \delta_{\phi}^2) / \cos^2 \alpha},$$

$$\delta_{\phi} = 1 - n_{\phi},$$

n_{ϕ} is the average refractive index of the multiple-layer coating.

Claim 4 (Currently Amended): ~~The A~~ plane diffraction grating according to claim 1 with grooves formed on a surface thereof, the plane diffraction grating being

rotated about a rotational axis which is normal to the surface, and being characterized in that a profile of the grooves at a radial area is determined depending on an azimuthal position ϕ of the area about a rotational center defined as a foot of the rotational axis on the surface of the plane diffraction grating for maximizing a diffraction efficiency of the radial area,

wherein the plane diffraction grating is a laminar type, and a depth h_ϕ of the grooves in an area along a line at the azimuthal angle ϕ is set as

$$h_\phi = \frac{\lambda}{2(\cos \alpha + \cos \beta)},$$

where λ is the wavelength of the light diffracted by the area, α is an angle of an incident ray from a normal to the surface of the plane diffraction grating in the area, and β is an angle of a diffraction ray from the normal.

Claim 5 (Previously Presented): The plane diffraction grating according to claim 4, wherein:

the surface of the plane diffraction grating is covered with a multiple-layer coating to improve reflectivity;

a unit thickness $d_{b\phi}$ of the multiple-layer coating in the area along the line at the azimuthal angle ϕ satisfies the equation:

$$m_b \lambda = d_{b\phi} (R_{\alpha\phi} \sin \alpha + R_{\beta\phi} \sin \beta),$$

where

U.S. Patent Application Serial No. 09/642,883
Response Under 37 C.F.R. §1.116 dated December 22, 2003
Reply to the Final Rejection of March 20, 2003
Attorney's Docket No. 001035

m_b is the diffraction order,

$$R_{\alpha\phi} = \sqrt{1 - (2\delta_\phi - \delta_\phi^2) / \cos^2 \alpha}, \quad R_{\beta\phi} = \sqrt{1 - (2\delta_\phi - \delta_\phi^2) / \cos^2 \beta},$$

$$\delta_\phi = 1 - n_\phi,$$

n_ϕ is the average refractive index of the multiple-layer coating.

Claim 6 (Canceled).

Claim 7 (Currently Amended): The An optical system ~~according to claim 6,~~
comprising:

a plane diffraction grating having grooves on a surface of the plane
diffraction grating whose profile at an area is determined depending on an
azimuthal position ϕ of the area about a rotational center defined as a foot of a
rotational axis which is normal to the surface for maximizing a diffraction efficiency
at the area;

a mechanism for rotating the plane diffraction grating about the rotational
axis;

an incidence optical system for casting a converging beam of light on a point
of the surface of the plane diffraction grating, the point being apart from the
rotational center.

wherein the plane diffraction grating is a blazed type, and a blaze angle θ_0 of the grooves in an area along an original line at the azimuthal angle $\phi=0$ which is perpendicular to the grooves is set as:

$$\theta_0 = \frac{\alpha + \beta}{2},$$

where α is an angle of an incident ray from a normal to the surface of the plane diffraction grating in the area, and β is an angle of a diffraction ray from the normal, and

a blaze angle θ_ϕ of the grooves in an area along a line at the azimuthal position ϕ is set as:

$$\sin \theta_\phi = \sin \theta_0 \sqrt{\frac{1 + \tan^2 \phi}{1 + \tan^2 \phi \sin^2 \theta_0}}.$$

Claim 8 (Previously Presented): The optical system according to claim 7, wherein:

the surface of the plane diffraction grating is covered with a multiple-layer coating to improve reflectivity;

a unit thickness $d_{b\phi}$ of the multiple-layer coating in the area along the original line at the azimuthal angle ϕ satisfies the equation:

$$m_b \lambda = 2d_{b\phi} R_{\alpha\phi} \cos(\alpha - \theta_0)$$

where

U.S. Patent Application Serial No. 09/642,883
Response Under 37 C.F.R. §1.116 dated December 22, 2003
Reply to the Final Rejection of March 20, 2003
Attorney's Docket No. 001035

m_b is the diffraction order,

λ is the wavelength of the light diffracted by the area,

$$R_{\alpha\phi} = \sqrt{1 - (2\delta_\phi - \delta_\phi^2) / \cos^2 \alpha},$$

$$\delta_\phi = 1 - n_\phi,$$

n_ϕ is the average refractive index of the multiple-layer coating.

Claim 9 (Currently Amended): ~~The~~ An optical system ~~according to claim 6,~~
comprising:

a plane diffraction grating having grooves on a surface of the plane diffraction grating whose profile at an area is determined depending on an azimuthal position ϕ of the area about a rotational center defined as a foot of a rotational axis which is normal to the surface for maximizing a diffraction efficiency at the area;

a mechanism for rotating the plane diffraction grating about the rotational axis;

an incidence optical system for casting a converging beam of light on a point of the surface of the plane diffraction grating, the point being apart from the rotational center,

wherein the plane diffraction grating is a laminar type, and a depth h_ϕ of the grooves in an area along an original line at the azimuthal angle ϕ is set as

$$h_{\phi} = \frac{\lambda}{2(\cos \alpha + \cos \beta)},$$

where λ is the wavelength of the light diffracted by the area, α is an angle of an incident ray from a normal to the surface of the plane diffraction grating in the area, and β is an angle of a diffraction ray from the normal.

Claim 10 (Previously Presented): The optical system according to claim 9, wherein:

the surface of the plane diffraction grating is covered with a multiple-layer coating to improve reflectivity;

a unit thickness $d_{b\phi}$ of the multiple-layer coating in the area along the line at the azimuthal angle ϕ satisfies the equation:

$$m_b \lambda = d_{b\phi} (R_{\alpha\phi} \sin \alpha + R_{\beta\phi} \sin \beta),$$

where

m_b is the diffraction order,

$$R_{\alpha\phi} = \sqrt{1 - (2\delta_{\phi} - \delta_{\phi}^2) / \cos^2 \alpha}, \quad R_{\beta\phi} = \sqrt{1 - (2\delta_{\phi} - \delta_{\phi}^2) / \cos^2 \beta},$$

$$\delta_{\phi} = 1/n_{\phi},$$

n_{ϕ} is the average refractive index of the multiple-layer coating.

U.S. Patent Application Serial No. 09/642,883
Response Under 37 C.F.R. §1.116 dated December 22, 2003
Reply to the Final Rejection of March 20, 2003
Attorney's Docket No. 001035

Claim 11 (Cancelled).

Claim 12 (Currently Amended): ~~The plane diffraction grating~~ A method of producing method according to claim 11, a plane diffraction grating having grooves on a surface thereof whose profile at an area is determined depending on an azimuthal position ϕ of the area about a rotational center defined as a foot of a rotational axis for maximizing a diffraction efficiency of the area, the method comprising the steps of:

coating a substrate with a photo-resist layer and forming a photo-resist mask from the photo-resist layer according to a preset pattern of groove arrangement;

covering the photo-resist mask with a sector mask having an opening of a narrow sector whose apex is set at the rotational center;

etching the substrate over the sector mask with an appropriate etching condition depending on a rotational position of the sector mask about the rotational center;

rotating the sector mask by an angle of the apex of the narrow sector; and repeating the etching process and the mask rotating process until the narrow sector sweeps the surface of the substrate.

wherein the plane diffraction grating is a blazed type, and the etching condition in the etching process is such that:

a blaze angle θ_0 of the grooves in an area along an original line at the azimuthal angle $\phi = 0$ which is perpendicular to the grooves is set as

$$\theta_0 = \frac{\alpha + \beta}{2},$$

where α is an angle of an incident ray from a normal to the surface of the plane diffraction grating in the area, and β is an angle of a diffraction ray from the normal, and

a blaze angle θ_ϕ of the grooves in an area along a line at the azimuthal position ϕ is set as

$$\sin \theta_\phi = \sin \theta_0 \sqrt{\frac{1 + \tan^2 \phi}{1 + \tan^2 \phi \sin^2 \theta_0}}.$$

Claim 13 (Previously Presented): The plane diffraction grating producing method according to claim 12, wherein the surface of the plane diffraction grating is then covered with a multiple-layer coating to improve reflectivity, and:

a unit thickness $d_{b\phi}$ of the multiple-layer coating in the area along the original line at the azimuthal angle ϕ satisfies the equation:

$$m_b \lambda = 2d_{b\phi} R_{\alpha\phi} \cos(\alpha - \theta_0)$$

where

m_b is the diffraction order,

λ is the wavelength of the light diffracted by the area,

$$R_{\alpha\phi} = \sqrt{1 - (2\delta_\phi - \delta_\phi^2) / \cos^2 \alpha},$$

$$\delta_\phi = 1 - n_\phi,$$

n_ϕ is the average refractive index of the multiple-layer coating.

Claim 14 (Currently Amended): ~~The plane diffraction grating~~ A method of producing method according to claim 11, a plane diffraction grating having grooves on a surface thereof whose profile at an area is determined depending on an azimuthal position ϕ of the area about a rotational center defined as a foot of a rotational axis for maximizing a diffraction efficiency of the area, the method comprising the steps of:

coating a substrate with a photo-resist layer and forming a photo-resist mask from the photo-resist layer according to a preset pattern of groove arrangement;

covering the photo-resist mask with a sector mask having an opening of a narrow sector whose apex is set at the rotational center;

etching the substrate over the sector mask with an appropriate etching condition depending on a rotational position of the sector mask about the rotational center;

rotating the sector mask by an angle of the apex of the narrow sector; and

repeating the etching process and the mask rotating process until the narrow sector sweeps the surface of the substrate,

wherein the plane diffraction grating is a laminar type, and the etching condition in the etching process is such that:

a depth h_ϕ of the grooves in an area along a line at the azimuthal angle ϕ is set as

$$h_\phi = \frac{\lambda}{2(\cos \alpha + \cos \beta)},$$

where λ is the wavelength of the light diffracted by the area, α is an angle of an incident ray from a normal to the surface of the plane diffraction grating in the area, and β is an angle of a diffraction ray from the normal.

Claim 15 (Previously Presented): The plane diffraction grating producing method according to claim 14, wherein the surface of the plane diffraction grating is then covered with a multiple-layer coating to improve reflectivity, and:

a unit thickness $d_{b\phi}$ of the multiple-layer coating in the area along the line at the azimuthal angle ϕ satisfies the equation:

$$m_b \lambda = d_{b\phi} (R_{\alpha\phi} \sin \alpha + R_{\beta\phi} \sin \beta),$$

where

U.S. Patent Application Serial No. **09/642,883**
Response Under 37 C.F.R. §1.116 dated December 22, 2003
Reply to the Final Rejection of March 20, 2003
Attorney's Docket No. 001035

m_b is the diffraction order,

$$R_{\alpha\phi} = \sqrt{1 - (2\delta_\phi - \delta_\phi^2) / \cos^2 \alpha}, \quad R_{\beta\phi} = \sqrt{1 - (2\delta_\phi - \delta_\phi^2) / \cos^2 \beta},$$

$$\delta_\phi = 1 - n_\phi,$$

n_ϕ is the average refractive index of the multiple-layer coating.